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Comparing Gin and Mill Cleaning in terms of Quality and Processing Performance

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Comparing Gin and Mill Cleaning in terms of Quality and Processing Performance

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Abstract

In today's highly competitive and diverse global textile market, product quality has become of paramount importance. In order for spinners to produce yarns that can be turned into high quality woven and knitted fabrics with little or no difficulty, emphasis needs to be placed on fibre quality and the maintenance of this quality through processes such as ginning. This study showed that although custom ginning resulted in cotton with higher trash content and a lower classing grade, fibre properties such as staple length, length uniformity, short fibre and nep content improved. The study also found that the textile mill can adequately cope with higher trash content with no detrimental effects on processing performance and yarn quality. Indeed, there were slight improvements with custom ginned cotton.

Introduction

The purpose of ginning is to separate the cotton fibre from the seed and produce cotton lint which is a saleable and processable commodity. The layout, size, type, and technology of the gin may take on a number of forms, which depend on the type of cotton grown, the production and harvesting conditions and economic factors, as well as on customer requirements. In essence, modern ginning is a combination of thermal, pneumatic and mechanical processes (Anthony and Bragg 1987), there essentially being two types of gins, namely saw gins and roller gins.

Historically, the process of separating the lint from the seed was done either by hand or with some kind of roller gin, which was laborious and slow, and which has now largely been replaced by saw ginning. The invention and commercialization of the saw gin resulted in an immediate and dramatic increase in cotton production worldwide (Dever 1986, Mayfield and Anthony 1994).

Irrespective of which method is used to gin cotton, the ginner has two objectives:

1. To produce lint of sufficient quality and quantity to enhance and maximise the return to the grower

2. To produce a fibre with minimum damage to satisfy the demand from the spinner and the consumer (Anthony 1994, Anon 2001).

Ginning is, therefore, an essential link between the cotton grower and the cotton spinning mill. The gin, however, can, at best, only maintain the natural quality of cotton taken from the field - never improve it.

Despite the introduction and acceptance of High-Volume Instruments (HVI), which measures staple length, strength and micronaire, cotton is still largely classed subjectively on the basis of grade (trash, colour, and preparation). The fact that the grade still plays a crucial role in determining the price paid for cotton, often forces gins to over clean the cotton, so as to achieve a superior grade which results in an increased price being paid for the cotton lint and therefore a better return for the grower. Unfortunately, this is often to the detriment of fibre quality, as this can adversely affect fibre length and uniformity, nep and seed coat levels and size, as well as short fibre levels, which will affect the textile performance and value of the cotton. Ginning represents, in essence, a compromise between trash content and fibre quality, with each mechanical or pneumatic device used to clean and gin cotton leading to an increase in nep and short fibre content (Figure 1) (Anon 1932, Delany 1959, Spencer 1985, van Doorn 1986, Mayfield 1988, Miles 1989, Rutherford, McKenzie et al. 1991, Columbus 1993, Mangialardi, Baker et al. 1994, MacDonald 1997, MacDonald 1997, Desai and Thombare 1998, Anon 2001, Bagshaw 2010).

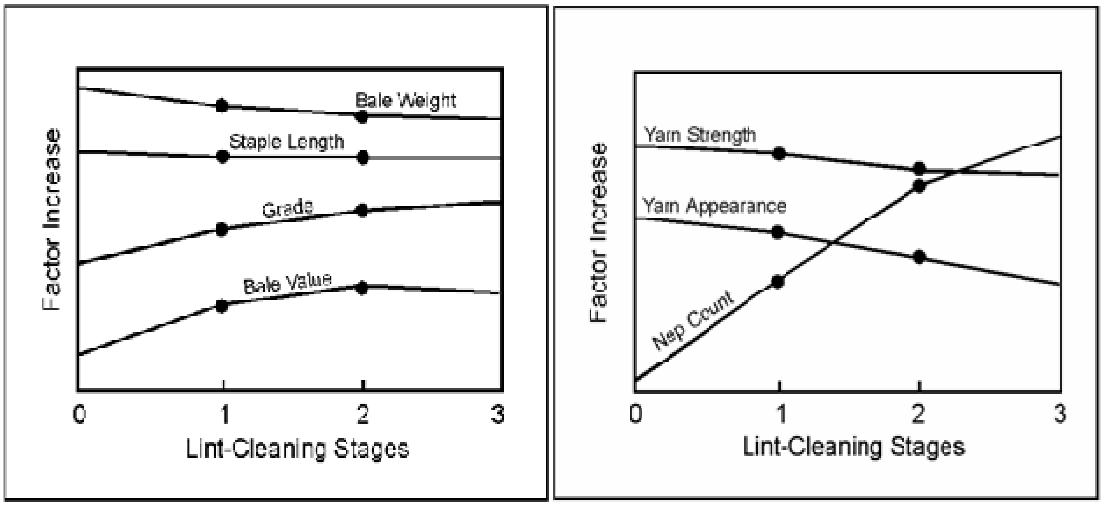

Figure 1. Compromise between trash removal and fibre quality (Mangialardi, Baker et al. 1994)

In actual fact, as classing grade is often a poor indicator of the true spinning value of the lint, some textile mills offer price premiums for cotton that is harvested, ginned (e.g., custom ginning) and shipped according to strict specifications. The specifications may include the number of lint cleaners, temperature, and moisture, speed, gin type, and, in some cases, also the cotton variety and the harvesting and storage methods. Custom ginning contracts normally result in a better fibre length and length uniformity, lower short fibre, nep and seed coat content and a reduction in pin trash (Anon 1960, Backe 1988, Johnson , Mayfield et al. 1994, Hahn 1996, Kaplan 1996, Anon 2003).

Several studies have been undertaken to investigate the consequence, in terms of fibre quality, of moving the cleaning operation from the gin to the textile mill. The general conclusion was that, irrespective of where the cleaning takes place, cotton that was subjected to the least amount of cleaning will produce yarns of superior quality (Cocke, Mangialardi et al. 1985, Lalor 1989). From a study conducted in 1985 to 1987, it was concluded that fibre damage was more closely related to the cleaning efficiency of the cleaner used than to the actual type of cleaner (Baker, Bragg et al. 1989, Lalor 1989).

The arguments in favour of cleaning at the gin, rather than at the spinning mill, are (Schlichter, Baker et al. 1995, Schlichter and Kuschel 1995):

- Higher grades
- Lower transport costs from the gin to the spinning mill

- Easier disposal of the trash at the gin than at the spinning mill

On the other hand, cleaning at the spinning mill, rather than at the gin, has the following advantages (Schlichter, Baker et al. 1995, Schlichter and Kuschel 1995);

- More-controlled cleaning conditions
- Lower throughput, resulting in better cleaning capacity
- Positive influence on fibre and yarn quality, the cotton being stressed much less in the spinning mill than in the gin.

From studies, conducted with two varieties from the 1985 crop at Stoneville, MS, it was concluded that minimum cleaning should take place at the gin, with the best overall cleaning sequence being the use of one lint cleaner, and that most of the cleaning should take place at the mill (Columbus, Bel et al. 1990, Columbus, Bel et al. 1990, Bel, Simpson et al. 1991). This regime resulted in a better-quality cotton fibre, and consequently in better spinning and weaving efficiency, as well as overall fabric quality (Bel - Berger and Von Hoven 1997). This was also found in a study conducted on a single cotton variety during 1986 to 1988 (Columbus 1993). In another study, conducted in 1986, cotton lint was ginned under four different conditions, ranging from standard (2 lint cleaners) to intermediate (1 lint cleaner) to minimal (extractor feeder and gin stand only), and then processed on standard spinning mill equipment, with the equipment selected to cope with the differences in gin cleaning. According to this study, there were no significant differences in the quality of the ring-spun carded yarns produced from the different cotton lots, although there were significant differences in the amounts of waste removed, as well as processing performance, in terms of ends down, with the intermediate treatment providing the optimum return to the grower and increased productivity in the textile mill (Anthony, Bragg et al. 1987, Bragg, Anthony et al. 1987).

In a large study, conducted from 1988 to 1991, seed-cotton was subjected to different treatments, ranging from normal to limited to special. The seed-cotton was then ginned on a conventional saw-gin and subjected to 0, 1 and 2 lint cleaners, respectively. This cotton was then processed in a spinning mill, using 1, 2 and 3 mono cylinder cleaners, respectively, carded and processed into 22 tex rotor-spun yarn. From the results of the study, it was concluded that the seed cotton cleaning did not have a significant effect on fibre and yarn quality, and that one lint cleaner, with two beater type mill cleaners, produced fibre with maximum bale values, without significantly lowering spinning performance and yarn quality (Baker, Price et al. 1994). This study also found that the cotton card was the most effective trash-removal device, followed by the lint cleaner (Baker, Price et al. 1994). A further study concluded that increased seed-cotton cleaning and a reduction in lint cleaners resulted in improved yarn quality and processing performance of rotor-spun yarns (Price 1992).

USDA/Trützschler conducted a full-scale trial in 1993, to determine the feasibility of transferring more of the cleaning to the mill. In this trial, rotor-spun yarns, produced from stripper cotton that had been harvested and ginned using typical ginning procedures, were compared with those produced from stripper cotton that had been subjected to either limited or no lint cleaning. No real differences, in neps, hairiness, strength and uniformity in fibre as well as yarn properties, were found. Nevertheless, cleaning of the cotton at the gin to a trash level of 1.5 to 2%, did benefit the processing performance and quality of the yarn (Schlichter, Baker et al. 1995, Schlichter and Kuschel 1995).

Studies conducted in Australia in 1998 and 1999 found that there were statistically significant differences when using zero, one or two lint cleaners. Increasing the number of lint cleaners resulted in a decrease in fibre length and length uniformity and increased nep and short fibre content (Roberts 2002).

A study conducted in Pakistan in 2002 concluded that a modern blowroom cleaning equipment can cope with higher trash levels without affecting fibre length and length uniformity; dependant on machine settings (Nawaz, Shahbaz et al. 2003)

The work reported in this paper was conducted at the same time as a previous reported study (van der Sluijs 2022) which focused on the relevance of colour grade on yarn manufacturing. This study focused on investigating whether a modern blowroom could cope with higher levels of trash and what the potential benefits and trade-offs would be for both the grower and spinner.

Materials and Methods

The study was conducted with seed cotton harvested from one field which was subjected to standard management practices for irrigated cotton in Australia. The field was subjected to two harvest aids by air, with a mixture of leaf defoliant, boll opener and defoliant spray oil and thereafter harvested by a spindle harvester. The ambient air conditions of the field (temperature and relative humidity) were monitored to ensure that moisture content was ≤ 12%. This ensured no excessive drying was needed during the ginning process.

Two conventional modules were ginned under standard commercial conditions with standard processing stages required for spindle harvested Upland cotton to achieve base grade. The gin was a high-capacity gin equipped with 4 x 161 Continental Eagle saw gin stands followed by Continental 24D and 16D controlled batt saw-type lint cleaners in tandem that can produce up to fifty bales per hour.

To examine lint cleaning effects three cleaning treatments were used:

1. Standard using two lint cleaners which is the most common.
2. Custom using one lint cleaner.
3. Zero using no lint cleaners.

Classing samples, from opposite sides, of each bale were collected at the gin after bale formation, with all these bale samples subjected to objective measurement by HVI. Samples were evaluated for fibre length in terms of upper half mean length (UHML in mm), length uniformity (UI%), short fibre index (fibres shorter than 12.7 mm) (SFI%) bundle strength in g tex^{-1} (STR) and micronaire (MIC). Further testing was conducted by an MDTA-3 instrument to further quantify trash (T%) (500 μm) and dust (D%) (15 μm) with fibre maturity and fineness determined by FMT2.

Lint, card, and 2nd passage drawframe sliver samples were also evaluated by AFIS to determine fibre nep (FN), trash (TC) (> 500 μm), dust count (DC) (< 500 μm), nep (NS) and trash (TS) size in micrometer (μm) and visible foreign matter (VFM%).

Visual classing of the lint was conducted to determine colour (CG),visible trash (LG) and preparation (PRP) according to the Universal Upland Grade Standards as established by USDA-AMS.

Yarns were assessed for evenness and imperfections by Uster 4-SX with strength and elongation assessed by Uster Tensorapid 3.

All samples were conditioned under standard conditions of 21+/-1°C and relative humidity % of 65+/-2 prior to testing.

Three bales from each lint cleaner treatment (e.g., 3 bales x 3 treatments = 9 bales) were processed at CSIRO's textile mill in Geelong under identical conditions using machines set to industry standard settings and production speeds.

The cotton mill consisted of Trützschler blowroom incorporating a bale opener CS, Cleanomat CXL - 3 and Material Reserve MSL 1200 followed by a DK 903 carding machine and two drawing passages by a HSR 1000 drawframe. This was followed by:

- For ring-spun carded yarns (RF); followed by a Zinser 660-FU roving frame and Zinser RM 350 ringframe and a Schlafhorst AC 238 winding machine.
- For rotor-spun yarns (Rotor); followed by a Schlafhorst Autocoro with SE-11 spin boxes.
- For air-jet spun yarns (MVS); followed by a further drawframe passage and a Murata MVS 810 vortex spinning frame.

Each lint cleaner treatment was subject to spinning trials over a range of yarn counts, ranging from medium to fine counts (25, 20, 17 & 15 tex). For brevity, this report will only list data for the 20 tex yarns. These yarns were processed and converted into fabric on a circular knitting machine, jet dyed and analysed.

To test for statistical differences between treatments an ANOVA was conducted on experimental data using Genstat 16.0 (Lawes Agricultural Trust, IACR Rothamsted, UK). Means for each parameter followed by the same letter are not significantly different at $P \leq 0.05$.

Results and Discussion

The warm, humid, and sunny conditions experienced during the growing season allowed for relatively easy defoliation and good harvesting conditions. This resulted in a mature fibre that was either within or better than the Australian base grade in terms of UHML ≥ 28.7 mm, UI% ≥ 80, strength ≥ 29 g tex^{-1} and G5 micronaire in the range of 3.5 to 4.9.

Fibre quality after ginning

The fibre quality results as obtained by the various instruments and visually are shown in Tables 1 & 2. As can be seen in Table 1 there were small positive statistical insignificant differences in terms of length, length uniformity and strength, and as expected with micronaire, maturity and fineness unaffected. These small differences were in all probability due to the fact that the cotton was very mature, with a study showing that more statistically significant difference would be obtained with immature cotton (Krifa and Holt 2013). However, the improvement in length uniformity was encouraging particularly as it was recognized that length uniformity was a major challenge to the cotton industry and required improvement to compete with man-made fibres (Martin, Ward et al. 2020).

As expected, classing grades fell with the reduction in lint cleaners due to the uneven appearance of the cotton and increased levels of trash and dust - see Table 2. Standard LC was classed as Strict Middling (21) with the custom and zero LC classed as Middling (31), which was still within the Australian base grade. Similarly, with a trash grade of 3 the standard and custom LC was also within the Australian base grade, with zero LC resulting in a trash grade of 4 which was above the Australian base grade with poor preparation.

There were also significant statistical differences in terms of nep, trash and dust content and size as shown in Table 2. Nep content and size decreased as the number of lint cleaners were reduced with trash and dust content, as measured by AFIS and MDTA-3, increasing and size increasing with reduced lint cleaning.

Table 1. HVI, FMT2 and visual determined fibre quality values

LC	HVI					FMT2		Visual		
	MIC	UHML	UI%	SFI%	STR	MR	FINE	CG	TG	PRP
2	4.71	29.33	83.5	3.83	31.27	1.04	176	21	3	Smooth
1	4.75	29.27	83.7	4.03	31.27	1.06	174	31	3	Smooth
0	4.72	29.54	84.2	3.33	31.98	1.06	171	31	4	Rough

Table 2. AFIS and MDTA-3 trash values

LC	AFIS						MDTA-3	
	FN	NS	TC	TS	DC	VFM%	T%	D%
2	177b	733b	54a	333a	266a	1.24a	1.21a	0.05a
1	174b	737b	60a	342a	290a	1.38a	1.46a	0.06a
0	131a	708a	105b	282b	774c	2.54b	3.10b	0.10b

Means for each parameter followed by different letter are significantly different at $P \leq 0.05$

Gin production data showed that lint turn-out improved by approximately 0.4% (equating to about one additional bale per three conventional modules ginned) as the number of lint cleaners decreased.

Fibre quality after mill cleaning

The trash results of card and drawframe sliver as measured by AFIS are shown in Table 3. As can be seen in Table 3 there were no statistically significant differences in terms of nep and trash content and size as well as dust content and VFM% between the three lint cleaning treatments.

Table 3. AFIS trash values for carded and 2 nd Passage drawframe sliver

LC	AFIS											
	Card Sliver						2nd Passage Drawframe Sliver					
	FN	NS	TC	TS	DC	VFM%	FN	NS	TC	TS	DC	VFM%
2	94	710	5	243	46	0.070	79	734	5	238	83	0.117
1	81	697	5	246	64	0.090	70	754	4	241	65	0.077
0	84	720	7	279	49	0.100	70	747	6	237	74	0.100

From Tables 2 and 3 and Figure 1 it was clear that, as has been shown in a previous study (Krifa and Holt 2007), the blowroom and carding machine were able to remove large amounts of trash and dust. The average reduction in trash count was 92%, with an 85% reduction in dust resulting in an overall reduction of 95% in VFM%. This high cleaning efficiency was not surprising as modern blowroom installations are expected to remove 40 to 70% of the trash with the carding machine able to remove 80 to 95 %, resulting in an overall cleaning efficiency of 95 to 99% (Klein 2014a). Clearly, the removal of such substantial amounts of trash and dust will require efficient waste removal systems.

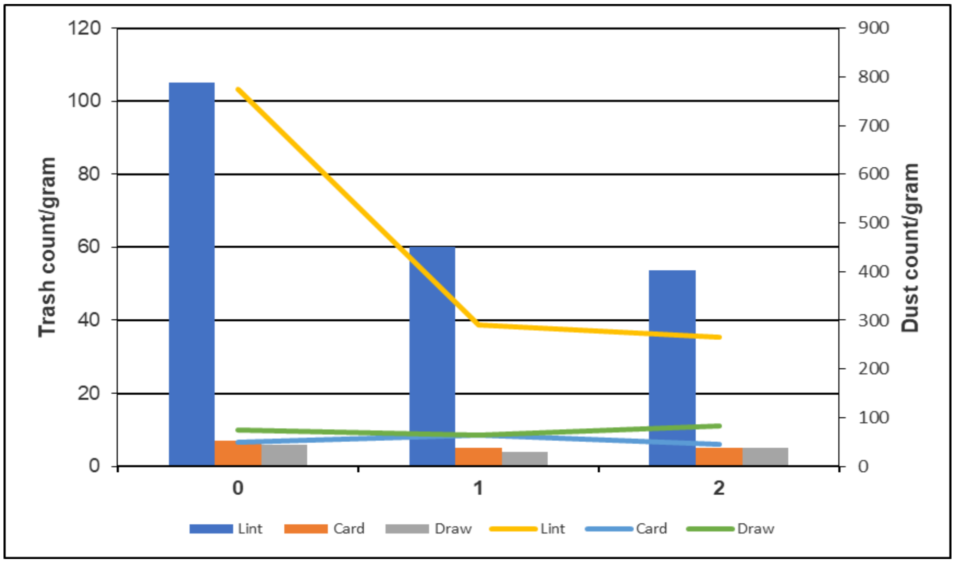

Figure 1. Trash and dust in lint and card and drawn sliver as assessed by AFIS

This is especially critical for rotor spinning where the accumulation of dust and trash in the rotor groove can result in issues with yarn quality, processing performance and wear and tear of expensive components (Ishtiaque and Das 2002). The trash and dust results for the yarns produced on the three spinning systems are shown in Figure 2. The results show that that the trash and dust count/gram were comparable irrespective of the number of lint cleaners used. Rotor-spun yarns had the least amount of trash and dust which was in all likelihood due to the action of the opening roller (Klein 2014b), followed by ring-spun yarns where the particles are ejected during ballooning, with the air-jet spun yarns containing the most trash and dust.

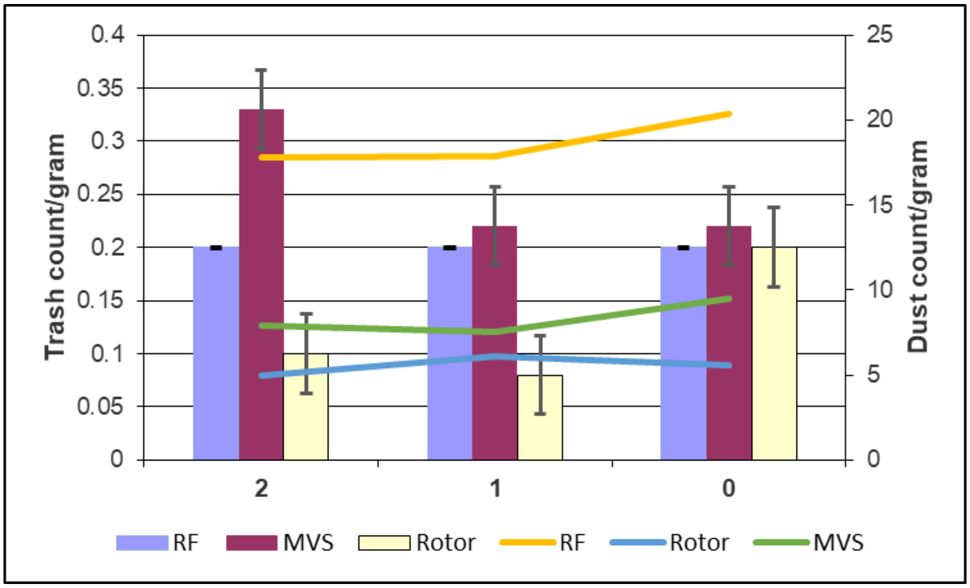

Figure 2. Trash and dust in yarn as assessed by Evenness tester

Nevertheless, despite these improvements, the extraction of the additional trash and dust will influence the productivity/utilization of the mill. This loss will need to be considered as will the capacity and efficiency of the waste removal plant.

Yarn Results

In general, the improvements in fibre properties such as fibre length, length uniformity and SFC, with reduced lint cleaning were reflected in slight improvements in the yarn properties for the ring and air-jet spun yarns, with no clear improvements for the rotor-spun yarns. These improvements were in yarn evenness and the number of yarn imperfections (including thin, thick places and neps)- see Figures 3 & 4.

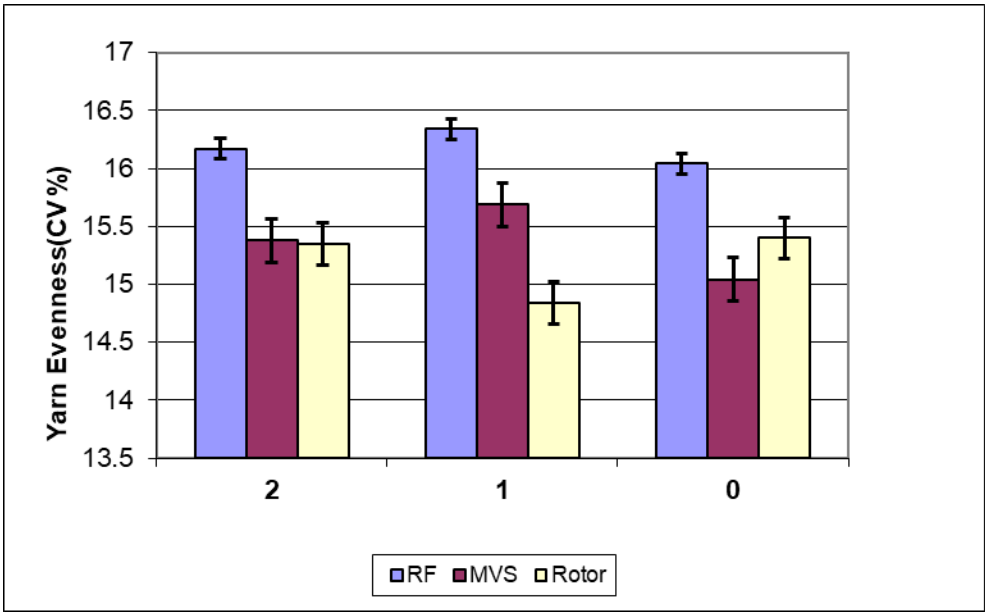

Figure 3. Evenness results for yarns

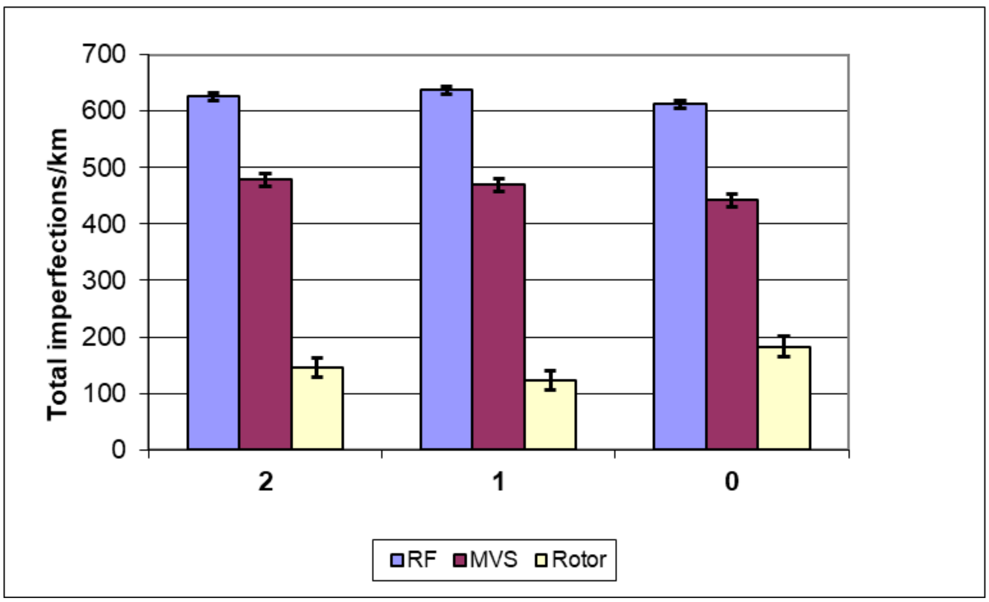

Figure 4. Total Imperfections for yarns

The reduction in the number of lint cleaners also had no real effect on yarn tenacity, in terms of strength and elongation – see Figure 5.

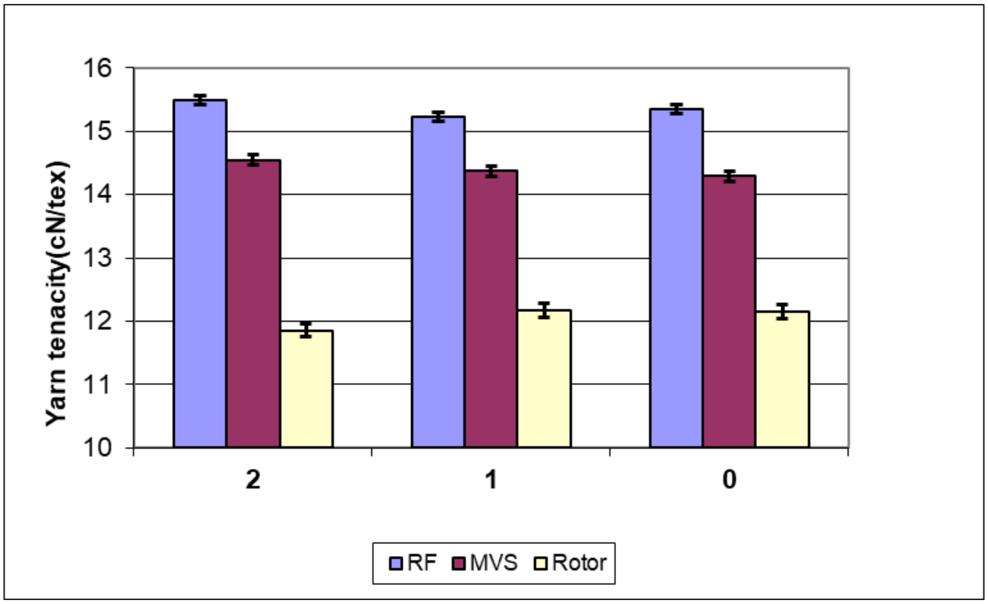

Figure 5. Strength results for yarns

End breakage rates

Another important method of determining the suitability of a certain type of cotton lint is to assess its processing performance. This entails the monitoring of the spinning process and the recording of the number of end breaks within a laid down and then expressing them in end breaks per 1000 spindle hours.

The end breakage results (not shown) indicated that there were no real differences in ring and rotor-spun yarns with LC treatments, with one LC providing the best ends down results for air-jet spun yarns.

Conclusion

This custom ginning trial has shown that reducing the number of lint cleaners to one or even zero resulted in increased lint turn out but lint with higher trash and dust content resulting in a lower classing grade. However, arguably more important fibre properties, from a textile perspective, such as length, length uniformity, short fibre and nep content were improved. As highlighted in a previous study, more focus on seed cotton cleaning and gin process control systems that provide in-line measurement of colour and leaf grade would greatly assist ginners in minimizing fibre damage and maximizing lint turn out (van der Sluijs 2020). Replacing the more aggressive controlled-batt saw lint cleaners with the gentler batt-less saw lint cleaners have also been proven to assist in preserving fibre quality.

Additionally, the value and importance of the blowroom process is often overlooked (Hilbare and Deshmukh 2019), with these trials demonstrating that the textile mill, especially the blowroom and card, can adequately cope with higher trash content with no detrimental effects on processing performance, and yarn and fabric quality.

These positive outcomes for this fairly coarse and mature custom ginned cotton suggests that further work with finer, but still within the G5 range cotton and immature cotton is justified, as it is expected to exhibit even greater benefits as these fibres would be more susceptible to mechanical damage during lint cleaning. Adding combing to the ring spinning processing route would also provide further information. This additional work would further emphasize the level of improvement that would be achievable by reducing the level of lint cleaning at the gin.

Acknowledgements

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